

KAMACITE-ENSTATITE INTERGROWTHS IN ENSTATITE CHONDRITES.

M. K. Weisberg, R. A. Fogel and M. Prinz. Dept. Earth and Planetary Sciences, American Museum of Natural History, New York, NY 10024.

INTRODUCTION. The enstatite meteorite clan includes a variety of primitive to differentiated materials that record a wealth of information on nebular and parent body processes including condensation, accretion, reduction, brecciation, metamorphism, and impact melting. Here we present the results of a petrologic study of kamacite-enstatite intergrowths, an unusual textural feature that occurs in many EH3 and EL3 chondrites. The purpose of this study is to understand the origin of these objects in relation to the parent body and nebular history of the E3 chondrites.

RESULTS. We studied thin sections of 6 EH3 (Parsa, Kota Kota, Qingzhen, PCA 91383, Y 74320, Y 691) and 5 EL3 (ALH 85119, EET 90299, PCA 91020, MAC 88136, QUE 93351) chondrites. Although the kamacite-enstatite intergrowths occur in most of the E3 chondrites studied, they appear to be more common in some of the EL3 chondrites. The kamacite-enstatite intergrowths are more commonly found outside of, but in a few cases within, chondrules. The metal is often present as irregular to spherical (chondrule-like) masses of Si-bearing kamacite, and in some cases is associated with other minerals including, schreibersite, taenite and troilite. The striking feature is that the enstatites occur in euhedral to subhedral tabular, lath, rod or even needle-shaped habits, enclosed within the kamacite (Fig. 1). In some cases, they appear to intrude into the kamacite from the exterior of the metal. The enstatites occur as single crystals and in clusters, and the ratio of enstatite to metal in the intergrowths varies widely. Similar intergrowths are found in the LEW87232 Kakangari-type chondrite [1], and euhedral enstatites within kamacite globules in EH4-5 chondrites (e.g., Abee) have been reported [2]. The enstatites are near-pure endmember MgSiO_3 in composition with Mn and Cr below the detection limits of the electron probe (<0.03 wt.%); although some have 0.1% Al_2O_3 . The enstatites in the kamacite are

compositionally similar to other pure enstatites in E3 chondrites, which were shown to have bright blue cathodoluminescence [3,4,5]. Blue luminescent enstatites in E3 chondrites were also shown to form as rims on chondrules and fragments and some have lath-like morphologies oriented orthogonal to the chondrule surface [5].

DISCUSSION. *Flux model.* A flux is a growth medium that is incompatible with the growing crystal and acts to speed up the kinetics of crystal formation. The use of fluxes to grow silicate crystals is well known in the experimental literature. V_2O_5 , PbO_2 and LiF have been used as fluxes to grow pyroxene crystals [e.g., 6]. It is possible that FeNi-FeS or FeNi-FeNiP melts may have acted as fluxes for enstatite growth, resulting in euhedral enstatite crystals observed in the metal.

Origin of the Kamacite-Enstatite Intergrowths. Three possible scenarios for the formation of the kamacite-enstatite intergrowths include: (1) growth from a melt through a parent body heating event, (2) growth from a melt through a nebular heating event, and (3) growth from vapor in the nebula. Formation of the kamacite-enstatite intergrowths by melting on a parent body is an unlikely scenario. There is no evidence of parent body melting in other portions of these unequilibrated chondrites. Rubin and Scott [2] described euhedral laths of enstatite within kamacite globules in EH4-5 chondrites and suggested that these resulted from impact melting of E chondrite material, followed by growth of the enstatite, and finally entrapment of the enstatite by late-stage crystallizing kamacite. In the E3 chondrites, however, there is no evidence of high degrees of shock or impact-melting. The E3 chondrites which have the most abundant intergrowths do not exhibit any indication of being more shocked than other E3s in which there are little or no kamacite-enstatite intergrowths. The spherical shape of some of the metal masses suggests that they may

have formed as free floating melt droplets, similar to chondrules. Flash heating of the metal-rich dust balls in the nebula may result in the observed kamacite-enstatite intergrowths. This scenario requires local nebular regions that are highly enriched in metal dust. Larimer and Bartholomay [7] showed that in a nebula gas with high C/O ratio, the condensation T's of silicates and oxides are shifted below that of Fe-metal. For example, under nebular C/O of 0.6 ($P=10^{-4}$ bars), corundum, diopside, olivine and enstatite condense at 1675, 1375, 1375 and 1275 K, respectively [8]. Fe condenses at 1375 K. Under a nebula C/O 1, conditions more appropriate to E chondrite formation [7], corundum no longer condenses and the condensation T's of diopside, olivine and enstatite are shifted to 1050, 1100 and 950 K, respectively. The condensation T of Fe, however, is still at 1375 K. From 1375 K to 1100, Fe will exist independently of these silicates. Agglomeration of condensates in this T-region would have a sizable metal component. Moreover, the data of [8] show that even under normal nebula C/O ratio of

0.6, Fe-metal comprises around 35 % of solids condensed in the 1350-1325 K range. Increased C/O ratio will serve to drastically increase this value. Alternatively, local regions of the nebula could become enhanced in metal-rich dust if the metal is expelled from silicate-rich chondrules during the heating and reduction of Fe associated with chondrule formation [e.g., 9]. An alternative model is that the enstatites are condensates that grew from a nebular vapor and were later trapped as relicts within kamacite-rich chondrules.

References: [1] Weisberg et al. (1996) GCA 60, 4253-4263. [2] Rubin and Scott (1997) GCA, in press. [3] Leitch and Smith (1982) GCA 46, 2083-2097. [4] Lusby et al. (1987) Proc. 17th LPSC 679-695. [5] Weisberg et al. (1994) Meteoritics 29, 362-373. [6] W. D. Carlson (1986) Contrib. Min. Petrol. 92, 218-224. [7] Larimer and Bartholomay (1979), GCA 43, 1455-1466. [8] Saxena and Eriksson (1983), GCA 47, 1865-1874. [9] E. A. King (1983) In: Chondrules and Their Origins (ed. E. A. King), 180-187.

Figure 1. Reflected light photo of a kamacite-enstatite intergrowth in the QUE 94594 EL3 chondrite (field of view=400 μ m). Kamacite (white) contains numerous inclusions of enstatite (gray) crystals which have lath- and rod-shaped morphologies.

